Logging Damage to Residual Trees Following Partial Cutting in a Green Ash-Sugarberry Stand in the Mississippi Delta

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Abstract: Partial cutting in bottomland hardwoods to control stand density and species composition sometimes results in logging damage to the lower bole and/or roots of residual trees. If severe, logging damage may lead to a decline in tree vigor, which may subsequently stimulate the production of epicormic branches, causing a decrease in bole quality and an eventual loss in value of the stand. To investigate this hypothesis, a partial cutting to remove pulpwood-sized trees (i.e., low thinning/improvement cutting) was performed in the summer of 1990 in a 45-year-old green ash-sugarberry stand located adjacent to the Mississippi River in west-central Mississippi. The goal of the thinning operation was to remove small trees of low-value species, particularly sugarberry, and to promote the growth of high-value residual trees, such as green ash. Thinning removed about 40 percent of the trees and 25 percent of the basal area, while increasing average stand diameter by about 12 percent. The partial cutting was also successful in increasing the relative proportion of green ash and decreasing the relative proportions of sugarberry and other species. The logging operation caused widespread damage to the residual stand, with about 62 percent of the residual trees being damaged at least to some extent. Damage to the lower bole and to exposed lateral roots of residual trees were the two most common types of damage. Damage to most trees was minor, but 35 percent of the residual trees experienced at least moderate logging damage. Sugarberry was more commonly damaged than was green ash. Most of the logging damage occurred during the skidding operation. Diameter growth of the residual dominant and codominant green ash averaged 0.39 in. during the first year after thinning. The partial cutting resulted in only a modest increase in the number of epicormic branches per tree, with most of the increases occurring in lower-crown-class trees, already under stress from suppression prior to harvest. Residual green ash and sugarberry trees of the upper crown classes produced very few new epicormic branches during the first year after harvest. These latter data must be considered preliminary in that the possible stimulation of the production of epicormic branches in damaged trees is thought to be a more long-term response to logging damage.

Partial cutting has long been an accepted practice used to control stand density and species composition. However, many managers of hardwood stands have failed to utilize this tool for fear that partial cutting will promote the development of epicormic branches on the boles of residual trees, and thus reduce their value as sawtimber. Bole quality, as manifested by log grade, is an extremely important determinant of the value of hardwood sawtimber. In general, USDA Forest Service log grades 1, 2, and 3 have value ratios of approximately 13:7:1, with butt logs much more

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likely to be grade 1 than upper logs (Stubbs 1986). Consequently, any silvicultural practice that may potentially result in log grade reduction can lead to a significant loss in value of the residual stand. Epicormic branches are frequent contributors to log grade reduction in partially cut hardwood stands.

In the past, the popular notion among foresters was that epicormic branches developed on residual trees following partial cutting solely in response to increased sunlight on the bole. However, many researchers have demonstrated that the phenomenon of epicormic branching is not as simple as a direct response to sudden exposure to sunlight. Brown and Kormanik (1970), in an excellent review article, concluded that epicormic branching is a function of several complex factors: (1) stand density, (2) tree vigor, (3) aspect, (4) position on the bole, and (5) genetics. They maintained that, although direct sunlight has a stimulatory effect on the release of suppressed buds, the sudden exposure to direct sunlight serves as a triggering mechanism for the production of epicormic branches' rather than as the direct cause of the phenomenon.

The concept that tree vigor plays a major role in determining the propensity of an individual to produce epicormic branches following partial cutting has been advanced by several researchers (Erdmann et al. 1985, Skilling 1957, Wahlenberg 1950). In each of these studies, trees of the lower crown classes (i.e., low-vigor trees) exhibited a much greater propensity for epicormic branching than did trees of the upper crown classes (i.e., high-vigor trees). These results imply that individual-tree vigor, in combination with genetic differences in resistance to epicormic sprouting among species, acts as the primary controlling mechanism for the production of epicormic branches, while sudden exposure to direct sunlight or some other type of disturbance serves as the primary triggering mechanism for the release of those suppressed buds that eventually develop into epicormic branches. These two factors, individual-tree vigor and sudden exposure to sunlight, interact with each other to control and trigger the phenomenon of epicormic branching.

Partial cutting not only results in the sudden exposure of residual stems to direct sunlight, it may also result in several types and severities of logging damage to those residual trees. Logging damage, particularly in the form of open wounds to the lower bole, has long been considered a serious problem associated with any type of partial cutting. Logging wounds that expose living sapwood may lead to eventual decay and/or discoloration of the wood in the tree. These types of damage not only result in loss of both log grade and log volume, they may also eventually lead to death of the tree. Hesterberg (1957) and Shigo (1966) conducted detailed investigations into the process of decay as a result of logging wounds in northern hardwoods. Hesterberg (1957) concluded that logging scars greater than 4 in. wide or that exposed more than 60-150 sq in. of sapwood were likely to develop decay within 10 years.

The extent of logging damage in partially cut hardwood stands may vary greatly from one stand to another, and depends on: (1) residual basal area, (2) size and maneuverability of equipment, (3) season of logging, (4) level of planning in the logging operation, and (5) skill and pride of equipment operators (Bruhn 1986). In a 60-year-old cherry-maple (*Prunus* L.-*Acer* L.) stand in West Virginia thinned to three different stocking levels, Lamson and others (1984) found that 22-45 percent of the unmarked stems were either destroyed or severely bent over during the logging operation, and that 18-42 percent of the residual standing trees received logging wounds that exposed living sapwood. However, the overall effect on residual stand basal area was slight because 99 percent of the destroyed trees and 55 percent of the wounded trees were less than 5 in. dbh.

Partial cutting, then, may have conflicting consequences, particularly in hardwoods. On one hand, partial cutting generally improves the species composition of the residual stand and promotes increased growth of residual trees. On the other hand, partial cutting may lead to the development of epicormic branches, especially on low-vigor trees, and may result in logging wounds that could eventually develop decay in residual stems. Both of these potential effects may lead to a significant loss in value of the residual stand.

This study addresses the effects of various types and severities of logging damage on tree vigor, epicormic branching, and bole quality of residual trees following a pulpwood thinning in a 45-year-old green ash-sugarberry (*Fraxinus pennsylvanica* Marsh.-*Celtis laevigata* Willd.) stand in the Mississippi Delta. The basic premise is that logging damage to the lower bole and/or lateral roots of residual trees will result in a decline in tree vigor, which will subsequently stimulate the production of epicormic branches, causing a decrease in bole quality and an eventual loss in value of the stand. The objectives of this study were: (1) to determine the effects of pulpwood thinning (i.e., low thinning) on residual stand structure, species composition, and growth; (2) to determine the extent, type, and severity of logging damage to residual stems following pulpwood thinning; and (3) to determine the long-term effects of logging damage on tree vigor, epicormic branching, and bole quality of residual stems following pulpwood thinning.

METHODS

Study Area

The study is located within a geographic area known as Indian Point, along the eastern side of the Mississippi River in southwestern Bolivar County, Mississippi. Indian Point is situated within the batture land between the Mississippi River on the west and the protective levee on the east, and is thus subject to prolonged inundation when the river floods. Most of the tract, including the study site, is owned by Anderson-Tully Company.

The study area consists of approximately 20 acres and is located within a 360-acre, even-aged stand composed primarily of green ash and sugarberry, with scattered large cottonwood (*Populus deltoides* Bartr. ex Marsh.). Stand age was approximately 45 years. The dominant soil type is Tunica clay, underlain at a depth of 2-3 ft by a loamy material. According to information supplied by Anderson-Tully Company, sawtimber volume averaged about 5,200 bd ft/acre (Doyle scale), but some portions of the stand contained as much as 8,500 bd ft of sawtimber per acre. Roughly 50 percent of the sawtimber volume was green ash, 30 percent was sugarberry, and the remaining 20 percent was cottonwood, pecan (*Carya illinoensis* (Wangenh.) K. Koch), and sycamore (*Platanus occidentalis* L.). The current stand developed beneath an original stand of pure black willow (*Salix nigra* Marsh.), which was harvested in 1968, when the green ash and sugarberry trees were pole-sized. Upper-crown-class trees in the current stand were predominantly green ash, whereas lower-crown-class trees were predominantly sugarberry. No cuttings had been made in the stand since 1968.

Plot Installation and Pre-Harvest Measurements

The approximately 20-acre study area is generally rectangular with dimensions of roughly 1,800 ft by 500 ft. Ten permanent sample plots were established systematically across the study area. Two parallel sampling lines, each consisting of five 1/2-acre circular plots, were established, for a sampling intensity of approximately 25 percent. Plots within lines are 400 ft apart; sampling lines are 240 ft apart.

Prior to treatment, species and dbh of each tree on the plot was recorded. After the stand was marked for thinning, but prior to harvest, crown class, total height, merchantable height, length and grade of all sawlogs, and number and location of existing epicormic branches were recorded on those trees designated as "leave" trees.

Thinning Operation

Anderson-Tully Company's objectives for the thinning operation were to increase growth of residual trees, to improve species composition, and to improve stand quality. Marking was performed by Company personnel. The primary marking rule was to remove all merchantable trees not of sawtimber size or quality (with the exception that pole-sized green ash trees someday capable of producing quality sawtimber were not removed). In effect, the thinning operation removed most pulpwood-sized sugarberry, as well as most low-quality sugarberry and green ash sawtimber. In general, the overall goal of the combined low thinning/improvement cutting was to decrease the relative proportion of sugarberry and increase the relative proportion of green ash in the residual stand, and to increase average tree size.

The logging operation was conducted by a private logging crew contracted by Anderson-Tully Company. Rubber-tired skidders were used to remove the merchantable products, in the form of longwood, from the woods. All material cut was marketed as pulpwood.

Post-Harvest Measurements And Logging Damage Assessment

After the logging operation, measurements and observations previously taken on "leave" trees were also taken on those trees marked to be cut, but, for whatever reasons, were not cut.

Logging damage to individual residual trees was assessed on the basis of four factors: (1) type of damage, (2) severity of damage, (3) location of damage, and (4) quadrant where damage occurred. Type of damage was classified as either (1) no damage, (2) root damage, (3) bole damage, (4) crown damage, (5) multiple damages, or (6) completely destroyed. Severity of damage was based on actual measurements of the dimensions of the wound, and was classed as (1) minor (less than 100 sq in. of exposed sapwood), (2) moderate (100-500 sq in.), or (3) severe (greater than 500 sq in.). Location of the damage was recorded as position on the bole: lower, middle, or upper. The quadrant where damage occurred was recorded as one of the four cardinal directions. Measurements of wound size and location, along with notes and observations on wound type and severity, were used to classify logging damage to individual trees according to these four factors.

RESULTS

Stand Structure And Species Composition

One of the primary objectives of the partial cutting operation was to improve stand structure and species composition. This goal was accomplished by reducing stand density, increasing average tree size, and by decreasing the sugarberry component and increasing the green ash component of the residual stand. The effects of the partial cutting on stand structure and species composition are summarized in Table 1.

Prior to harvest, the stand contained nearly 158 trees per acre, with an average basal area of 154 square feet. Average dbh across the stand was 12.1 in. Cutting removed nearly 59 trees per acre, with an average dbh of 10.4 in., representing about 38 square feet of basal area. The logging operation resulted in the destruction of 5 trees per acre, but because average dbh of these destroyed trees was only 5.4 in., the loss in basal area was only 1.0 square feet. After logging, the residual stand contained 94 trees per acre, with an average basal area of nearly 115 square feet. Average dbh of the residual stand was 13.6 in. The logging operation, then, through both cutting and accidental destruction of some small stems, removed about 40 percent of the trees and 25

Table 1.—Stand structure and species composition prior to and immediately following partial cutting in a green ash sugarberry stand in the Mississippi Delta

Stand Condition: Species	Trees per acre	Basal area	Average Dbh
		-ft²/ac-	-in.-
I. Pre-harvest			
Green ash	19.2	37.8	18.2
Sugarberry	100.2	83.2	11.3
Other species	38.4	33.0	11.3
All trees	157.8	154.0	12.1
II. Cut			
Green ash	1.0	1.6	16.7
Sugarberry	39.0	22.0	9.7
Other species	18.8	14.6	11.3
All trees	58.8	38.2	10.4
III. Destroyed			
Green ash	0.2	0.1	7.4
Sugarberry	3.2	0.6	5.5
Other species	1.6	0.3	4.9
All trees	5.0	1.0	5.4
IV. Post-harvest			
Green ash	18.0	36.1	18.4
Sugarberry	58.0	60.6	12.7
Other species	18.0	18.1	11.7
All trees	94.0	114.8	13.6

percent of the basal area, while increasing average stand diameter by about 12 percent. These data indicate that the goal of improving stand structure was achieved through the partial cutting operation.

The effects of the partial cutting on species composition are also presented in Table 1. Marking of the stand prior to harvest was very successful in discriminating against sugarberry and other low-value species, while favoring green ash. Harvesting removed approximately 42 percent of the sugarberry trees and about 53 percent of the trees of other species. Basal areas were reduced by 27 percent and 45 percent for sugarberry and other species, respectively. In contrast, green ash density was only negligibly reduced by the harvesting operation.

Consequently, the partial cutting was successful in increasing the relative proportion of green ash and in decreasing the relative proportions of sugarberry and other species. Prior to harvest, species composition, in numbers of trees, was 12 percent green ash, 64 percent sugarberry, and 24 percent other species. The residual stand contained 19 percent green ash, 62 percent sugarberry, and 19 percent other species. These figures represent modest but important changes in species composition. Similar trends were found for changes in composition, expressed as a percentage of basal area. Based on basal area, species composition prior to harvest was 25 percent green ash, 54 percent sugarberry, and 21 percent other species. Basal area of the residual stand consisted of 31 percent green ash, 53 percent sugarberry, and 16 percent other species.

The partial cutting had a marked impact on the diameter distribution of each species group and of the stand as a whole (Figure 1). Very few green ash trees were removed, having little effect on residual diameter distribution (Figure 1a). In contrast, sugarberry and the other species were heavily cut, especially in the 8-, 10-, 12-, and 14-inch dbh classes (Figure 1b and 1c). Unfortunately, trees of these low-value species in the 4- and 6-inch classes were generally too small for pulpwood and were not removed from the stand in any great quantity. Overall, the partial cutting changed the diameter distribution from one skewed towards the smaller dbh classes to one more regularly bell-shaped with highest densities in the 14- to 18- inch classes (Figure 1d). Because the majority of the trees in the 4- and 6-inch dbh classes were not removed, the manager will most likely be faced with the same problem in just a few years as these trees move upward into the pulpwood-sized classes.

Logging Damage To Residual Trees

The logging operation caused widespread damage to the residual stand, with about 62 percent of the residual trees being damaged at least to some extent (Table 2). Most of this damage occurred during the skidding operation, as tree-length logs dragged by the skidder scraped against the lower bole and/or exposed lateral roots of residual trees. Much of this damage could have been avoided through more careful skidder operation.

The frequency of logging damage varied somewhat among species groups (Table 2). Sugarberry was the most commonly damaged species, with 66 percent of the residual stems experiencing some degree of logging damage. Damage to green ash trees was less frequent, with approximately 52 percent of the residual stems being damaged. About 60 percent of the residual stems of other species were damaged. Skidder operators apparently utilized greater care when skidding logs near high-value residual green ash trees.

Across all species, there was little variation in the extent of logging damage among all crown classes, except suppressed (Table 2). Trees in the suppressed class were damaged less frequently than trees in the other crown classes. These smaller trees were probably more easily avoided by skidder operators and, therefore, were damaged less frequently. Unfortunately, upper-crown-class sugarberry trees were very commonly damaged during logging, with about 95 percent and 76 percent of the residual dominant and codominant sugarberry trees being damaged, respectively. Most of this damage was in the form of scrapes to the exposed lateral roots of these larger trees.

Table 2.—Extent of logging damage, by species and by crown class, following partial cutting in a green ash sugarberry stand in the Mississippi Delta. All values are in percent of residual trees damaged or destroyed.

Crown class	Green ash	Sugar-berry	Other species	All trees
Dominant	50.0	95.0	33.3	66.0
Codominant	54.9	75.8	70.8	69.0
Intermediate	40.0	71.0	66.7	65.2
Suppressed	57.1	51.2	58.5	53.5
All trees	51.6	66.0	60.2	62.2

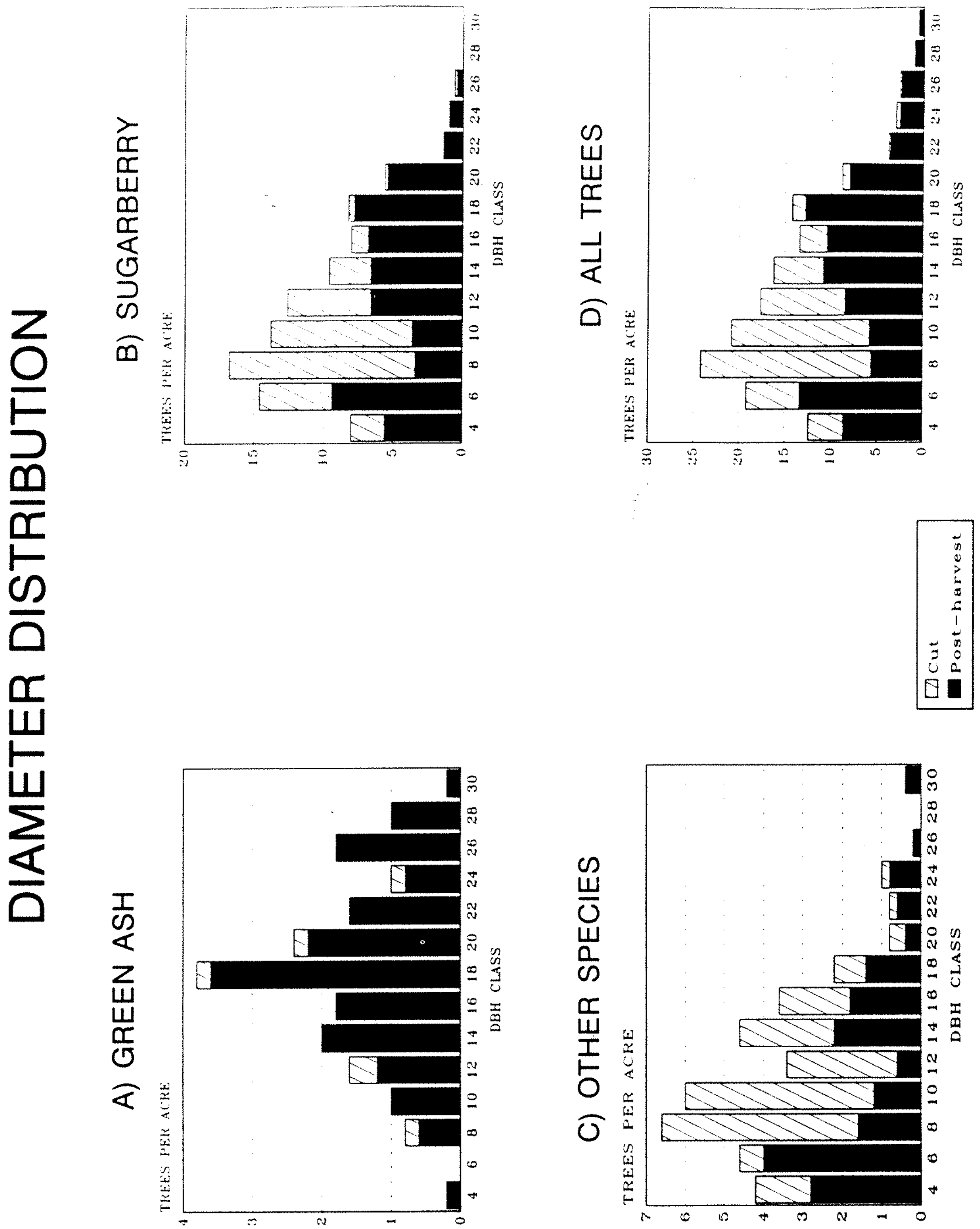

Figure 1.—Diameter distribution prior to and immediately following partial cutting in a green ash-sugarberry stand in the Mississippi Delta: A) green ash, B) sugarberry, C) other species, and D) all trees.

The type of logging damage inflicted on residual trees was classed as either root, bole, crown, multiple, or completely destroyed. The frequency of these various types of logging damage among species groups and among crown classes is summarized in Tables 3 and 4. Across all species and crown classes, damage to the lower bole and to exposed lateral roots of residual trees were the two most common types of damage. Multiple damages, typically a combination of damage to both bole and roots, were also common. Damage to the crowns of residual trees was infrequent because most of the cutting was "from below."

Table 3.—Type of logging damage, by species, following partial cutting in a green ash-sugarberry stand in the Mississippi Delta. All values are in percent.

Type of damage	Green ash	Sugar-berry	Other species	All trees
None	48.4	34.0	39.8	37.8
Root	17.5	19.3	16.3	18.4
Bole	18.7	18.9	23.5	19.8
Crown	1.1	2.3	1.0	1.8
Multiple	13.2	20.3	11.2	17.1
Destroyed	1.1	5.2	8.2	5.1
All types	51.6	66.0	60.2	62.2

There was very little variation among species groups in the distribution of these different types of logging damage, with the exception that multiple damages were most common in sugarberry (Table 3). The percentage of trees completely destroyed during logging was also greatest among the lower-value species.

On the other hand, there were differences among crown classes in the distribution of the various types of logging damage (Table 4). Damage to exposed lateral roots was much more common in upper-crown-class trees than in lower-crown-class trees. However, the occurrence of exposed lateral roots is generally more prevalent in large trees. Damage to the lower bole was much less common in dominant trees than in trees of the other crown classes, perhaps because skidder

Table 4.—Type of logging damage, by crown class, following partial cutting in a green ash-sugarberry stand in the Mississippi Delta. All values are in percent.

Type of Damage	Dom[1]	Codom[1]	Inter[1]	Sup[1]	All Trees
None	34.0	31.0	34.8	46.5	37.8
Root	27.7	30.5	19.1	4.3	18.4
Bole	8.5	18.4	20.2	23.8	19.8
Crown	2.1	0.6	0	3.8	1.8
Multiple	27.7	19.5	22.5	9.7	17.1
Destroyed	0	0	3.4	11.9	5.1
All types	66.0	69.0	65.2	53.5	62.2

[1]Dom - Dominant
Codom = Codominant
Inter = Intermediate
Sup = Suppressed

operators utilized more care when maneuvering around very large trees. The vast majority of trees destroyed during logging were in the suppressed crown class, with no upper-crown-class trees being destroyed. In short, the type of logging damage found in the residual stand was related much more to crown class and size of tree than to species.

The severity of the logging damage to residual trees was classed as either minor, moderate, severe, or completely destroyed, based primarily on the size of the wound. The distribution of these different severities of logging damage among species and among crown classes is summarized in Tables 5 and 6. Across all species and crown classes, damage to most trees was minor, but about 35 percent of the residual trees experienced at least moderate logging damage. Severity of the damage was not generally related to species, except that damage to green ash appeared to be somewhat less severe than damage to sugarberry and other species (about 26 percent of residual green ash trees had at least moderate damage as compared to 37 percent for sugarberry and 36 percent for other species). Severity was also not generally related to crown class, except that all the trees that were completely destroyed were lower-crown-class trees.

Table 5.—Severity of logging damage, by species, following partial cutting in a green ash-sugarberry stand in the Mississippi Delta. All values are in percent.

Severity of damage	**Green ash**	**Sugar-berry**	**Other species**	**All trees**
None	48.4	34.0	39.8	37.8
Minor	25.2	28.8	24.5	27.3
Moderate	19.8	22.6	21.4	21.8
Severe	5.5	9.4	6.1	8.0
Destroyed	1.1	5.2	8.2	5.1
All severities	51.6	66.0	60.2	62.2

Table 6.—Severity of logging damage, by crown class, following partial cutting in a green ash-sugarberry stand in the Mississippi Delta. All values are in percent.

Severity of damage	**Dom**[1]	**Codom**[1]	**Inter**[1]	**Sup**[1]	**All trees**
None	34.0	31.0	34.8	46.5	37.8
Minor	25.6	36.8	30.4	17.3	27.3
Moderate	29.8	27.6	24.7	13.0	21.8
Severe	10.6	4.6	6.7	11.3	8.0
Destroyed	0	0	3.4	11.9	5.1
All severities	66.0	69.0	65.2	53.5	62.2

[1]Dom = Dominant
Codom = Codominant
Inter = Intermediate
Sup = Suppressed

First-Year Diameter Growth

Diameter growth during the first year following partial cutting is summarized by species and by crown class in Table 7. Because growth histories of individual trees are not known and because no uncut plots are available, it is unknown whether these figures represent a significant response to the partial cutting. However, first-year diameter growth of the residual trees is certainly acceptable for these species on this type of site, particularly for the upper-crown-class trees. Dominant and codominant trees of all species averaged 0.33 in. of diameter growth during the first year, with dominant and codominant green ash averaging 0.39 in. and dominant and codominant sugarberry averaging 0.29 in. These figures compare favorably with average diameter growth rates reported by Putnam and others (1960) for dominant and codominant green ash and sugarberry trees on better sites. Particularly impressive is the first-year diameter growth of the dominant trees in the stand, which averaged better than 0.40 in. for all species. Expressed on a 10-year basis, dominant trees of all species are currently growing at the rate of 4.0 in. or better per decade, which is considered to be excellent diameter growth (Putnam et al. 1960).

Table 7.—First-year diameter growth, by species and by crown class, of residual trees following partial cutting in a green ash-sugarberry stand in the Mississippi Delta. All values are in inches.

Crown class	Green ash	Sugar-berry	Other species	All trees
Dominant	0.45	0.40	0.54	0.44
Codominant	0.35	0.26	0.25	0.28
Intermediate	0.18	0.17	0.36	0.20
Suppressed	0.15	0.13	0.15	0.14
All trees	0.35	0.22	0.27	0.25

Epicormic Branching

The effect of partial cutting on epicormic branching of residual trees is summarized by species and by size class in Table 8. Across all species and size classes, the number of epicormic branches per tree increased only slightly, from 0.9 prior to harvesting to 2.2 after one year. The largest increase occurred in trees of other species, which showed an increase of more than 4 branches per tree (from 2.3 to 6.5) during the first year. Green ash and sugarberry, species with little tendency for epicormic branching, showed only modest increases in the number of epicormic branches per tree.

Pulpwood-sized (dbh of 4-12 in.) trees of all species showed a greater propensity to produce epicormic branches than did sawtimber-sized (dbh greater than 12 in.) trees (Table 8). Again, much of this increase was found in trees of other species, principally elms (*Ulmus* L.). Epicormic branching in sawtimber-sized trees increased only slightly during the first year, with increases of less than one branch per tree found in each species. These differences in epicormic branching between size classes agree with the trend reported by Trimble and Seegrist (1973), i.e., that the larger, more vigorous, upper-crown-class trees have less propensity to produce epicormic branches than do the smaller, less vigorous, lower-crown-class trees.

Table 8.—Number of epicormic branches per tree, by species and by size class, prior to and one year following partial cutting in a green ash-sugarberry stand in the Mississippi Delta.

Species	Pulpwood		Sawtimber		All Trees	
	Pre	Yr 1	Pre	Yr 1	Pre	Yr 1
Green ash	0.3	2.0	0.1	0.9	0.1	1.1
Sugarberry	0.6	1.3	0.6	0.6	0.6	1.1
Other species	2.4	6.8	2.0	2.7	2.3	6.5
All trees	1.2	3.0	0.5	0.8	0.9	2.2

DISCUSSION

Partial cutting in this green ash-sugarberry stand was successful in improving stand structure and species composition, and in creating an environment favorable for increased growth of residual trees. Small, poorly formed individuals of low-value species, such as sugarberry, elm, and boxelder (*Acer negundo* L.), were removed from the stand in an attempt to favor high-value green ash trees. Stand density was reduced and species composition was altered in such a way as to promote the growth and development of desirable residual stems of valuable species. The end result of the partial cutting was to improve the quality and value of the residual stand. From this purely silvicultural perspective, the partial cutting was very successful.

Unfortunately, one of the potential consequences of partial cutting in any stand is logging damage to residual trees. Logging damage following partial cutting in this particular stand was quite extensive, with 62 percent of the residual trees being damaged at least to some extent. Most of the damage was minor, but 35 percent of the residual trees experienced at least moderate logging damage. Obviously, some degree of logging damage must be expected during any partial cutting operation. However, compared to other studies (Lamson et al. 1984), the amount of damage incurred during this study is excessive and much of it could have been avoided through more careful skidder operation.

There is a high probability for the introduction of pathogenic fungi through these logging wounds, an event that would severely reduce the value of the residual stand. Butt rot, the leading cause of cull in southern hardwoods, is very prevalent in stands that have experienced extensive logging damage to residual trees (Toole 1960). Although the rate of rot development within the tree varies with the specific fungus present and with the host tree, Toole (1960) reported average rates of upward spread of butt rot in green ash to be 3.4 ft after 20 years and 5.1 ft after 40 years. Rate of spread in sugarberry was 4.1 ft and 6.1 ft after 20 and 40 years, respectively (Toole 1960). Consequently, trees damaged during this study that do develop butt rot will lose a significant portion of their butt log by the time the stand is ready for final harvest. Because the butt log is the most valuable log in the tree, the effects on final value of the stand could be staggering.

Another possible consequence of logging damage to residual trees is a reduction in tree vigor that could subsequently stimulate the production of epicormic branches. The basic premise in this study is that logging damage may cause a significant loss of vigor in the tree, thus creating a stress that may be severe enough to promote the development of epicormic branches. The end result of this potential phenomenon would be a decrease in bole quality and an eventual loss in value of the stand. Stress-related production of epicormic branches in damaged trees will probably take several years to occur, as the gradual loss of vigor in damaged trees steadily results in an increasingly severe stress.

Consequently, a significant increase in the number of epicormic branches per tree was not expected during the first year, and results indicate that it did not occur. There was only a modest increase in the number of epicormic branches per tree, with most of the increases occurring in lower-crown-class trees. These trees were already under stress from suppression prior to harvest and the sudden exposure of the bole to sunlight following harvest probably triggered the production of epicormic branches on those trees. There was very little change in the number of epicormic branches found on trees of the upper crown classes. Those few upper-crown-class trees that did produce new epicormic branches exhibited slightly lower vigor than did upper-crown-class trees that produced no new epicormic branches. Consequently, these slightly less-vigorous trees were somewhat predisposed to the production of epicormic branches, such that the sudden exposure to direct sunlight following the partial cutting probably triggered the release of those suppressed buds that developed into new epicormic branches.

Partial cutting in this stand had conflicting consequences. On the one hand, it reduced stand density, improved stand structure and species composition, and increased diameter growth of residual trees. On the other hand, partial cutting resulted in extensive logging damage to residual trees. The long-term effects of this damage, in terms of both rot development and stimulation of epicormic branches, are unknown at this time. If these latter effects occur widely throughout the stand over time, the overall effect of the partial cutting on the value of the stand will be negative. However, if the development of rot and the production of epicormic branches are limited in the stand, the overall effect will be positive. Because logging damage in this stand was more widespread than necessary or expected, there is a greater probability of negative effects. However, if the logging operation is properly planned and implemented, damage to residual trees can be minimized and the full silvicultural benefits of partial cutting can be reaped by the manager. In this way, partial cutting can be utilized effectively as a tool to properly manage stands of southern hardwoods.

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